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Analyzing Indoor Environment of Minahasa Traditional House Using CFD

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Abstract

Raised floor can be found in many traditional buildings throughout Indonesia, however this element currently disappears from Indonesia modern architecture. One of possible reason is limited study conducted on raised floor house, therefore the benefits of raised floor element; especially its application in tropical climatic is never exposed. Minahasa Traditional House is a traditional raised floor house that still exists today. This paper will investigate thermal comfort conditions particularly wind velocity inside of Minahasa Traditional House using Computational Fluid Dynamic (CFD) analysis. Simulation on several variations of openings and stilts height is conducted to measure its effectiveness in creating thermal comfort. The result of the study will become a reference for modern architect to design modern house that incorporate design features from vernacular architecture.

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Keywords: raised floor; vernacular architecture; minahasa traditional house; CFD; thermal comfort;

1. Introduction

Minahasa Traditional House is wooden raised floor house originated from Tomohon, North Sulawesi. This house is build on top of 16-18 wooden stilts with 1.5 - 3 meter of height. Its roof shape is a combination between Hip and Gable Roof.

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Minahasa Traditional house consist of four rooms. First is 'Kolong', area beneath the floor that was used to store crops. Second is 'Lesar' is a terrace with no walls located before main entrance. Third is 'Sekey', located after main entrance, a reception room where resident receiving guest. Last area is Living room or 'Pores'. In the living room there are bedrooms, dining room as well as kitchen.

Minahasa traditional building is designed by adapting to tropical climate using passive design principles. These principles are:

- Roof opening and high ceiling to create stack effect.
- A large roof overhang and verandas to reduce solar gains.
- Wall and Roof opening to remain open for natural ventilation.
- Floor opening to allow air from beneath to flow into building.

Minahasa Traditional house's raised floor structure and roof shape, is allowing opening made not limited on the wall but also on the roof as well as on the floor. Thus allowing more wind to flow into the house.

Fig. 1 Minahasa traditional house

1.1. Raised Floor House and Natural Ventilation

Airflow beneath the floor cooling the building's floor as well as decrease humidity. Raised floor will make positive impact on thermal comfort inside the building. Idea of using cross air under the floor as passive design was introduced by Tahir [1]. They studied raised floor house in relation to its potential as a model for ultralow energy building. They mentioned that there are five advantages of the raised floor in a hot and humid climate. These advantages are:

a. The raised floor increases air movement in and out of building.
b. Increasing the floor level from ground may require additional cost but the cost could in the long run be justifiable considering the addition space achieved and the possible functions.
c. Effective counter measures from animals and insects as well as comfort from the constant havoc of flash floods.
d. More privacy with additional consideration to detailed wall design. Floor rose at a level of more than that of a normal human height automatically restrict views from pedestrians.
e. Better security and fewer requirements of specific facilities normally associated with most terrace housing schemes.
f. Better views and option for integration of landscape design.

In addition, a method of improving thermal comfort on raised floor house was also suggested by introducing alternative floor construction, adjustable floor louvers. They argue that adjustable floor louvers could assist in diverting some of the cross air from under the floor into the house and through to the rear. Another study by Sapian [2], who conducted a study on high-rise residential buildings using Computational Fluid Dynamic (CFD) simulation found that wind is stronger in the building with pilot is than in the one without. This finding confirms that natural ventilation/cross air from under the floor is potentially developed as a method of improving thermal comfort on raised floor house.

2. Methodology

This research simulates natural ventilation particularly ‘wind driven ventilation’ inside Minahasa Traditional House. Twelve variations of ‘test house’ (TH) were used for this simulation. Three openings with same area were made on these models; however each model is due to different opening position and stilts height. TH grouped into four groups: wall opening; roof opening; wall and roof opening; wall, roof and floor opening.

This simulation begins with creating simplified computational 3D model of Minahasa Traditional House using Autodesk Revit. These test models than exported to Autodesk Simulation CFD where a wind tunnel simulation is conducted. There are three boundary conditions to define the inputs of the simulations, these conditions are:

a. Wind Velocity; used as an inlet boundary condition
b. Pressure; used as an outlet condition
c. Slip/Symmetry; this condition causes the fluid to flow along a wall instead of stopping at the wall, which typically occurs along a wall

The reference wind velocity is considered to be 1.0 m/s. This reference is based on mean maximum wind speed between hot and rainy season in Indonesia [3]. Wind direction is come from one side, front side of the building, to resemble current housing condition that only has front entrance.

There are four points of measurement on each test model. First point (point 1) is inside the house, approx. 1.5 meter above the floor. This point is to measure wind velocity perceived by resident. Other points (point 2, 3 and 4) are approx. 0.3-meter bellow the floor at the front, middle and rear side of the test model. These points are to measure wind velocity beneath the building, to determine which area is suitable to make floor opening.

Table 1. Test model and its variations.

No	Code	Wall Opening	Roof Opening	Floor Opening	Stilts Height	Opening Position
1	TM1-1	Yes	No	No	1M	Wall
2	TM1-2	Yes	No	No	2M	Wall
3	TM1-3	Yes	No	No	3M	Wall
4	TM4-1	No	Yes	No	1M	Roof
5	TM4-2	No	Yes	No	2M	Roof
6	TM4-3	No	Yes	No	3M	Roof
7	TM2-1	Yes	Yes	No	1M	Wall + Roof
8	TM2-2	Yes	Yes	No	2M	Wall + Roof
9	TM2-3	Yes	Yes	No	3M	Wall + Roof
10	TM3-1	Yes	Yes	Yes	1M	Wall + Roof + Floor
11	TM3-2	Yes	Yes	Yes	2M	Wall + Roof + Floor
12	TM3-3	Yes	Yes	Yes	3M	Wall + Roof + Floor

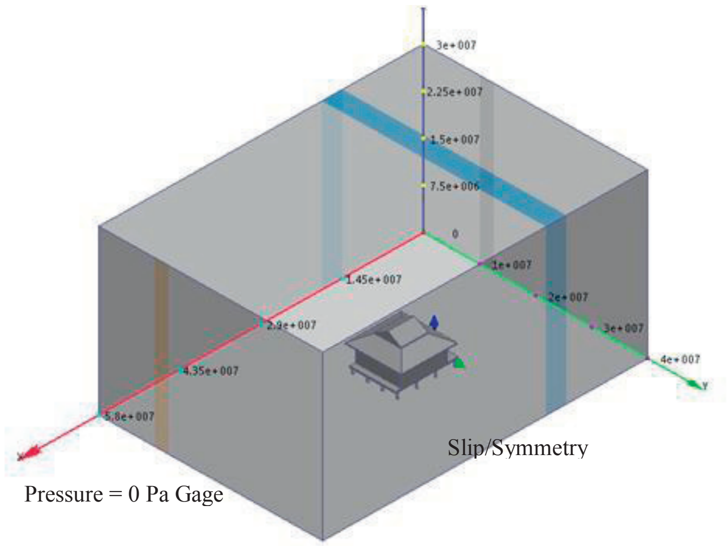


Fig. 2 Boundary conditions in the CFD model.

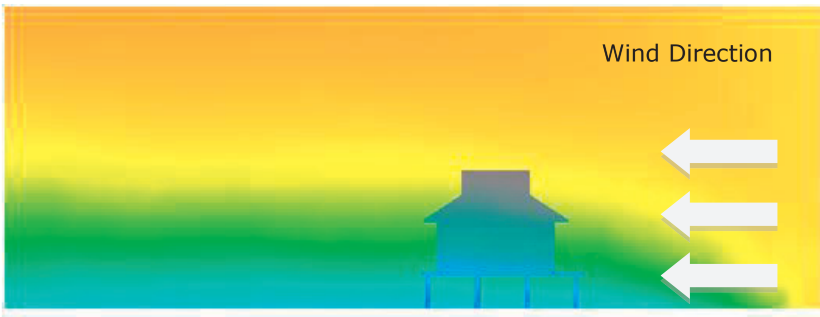
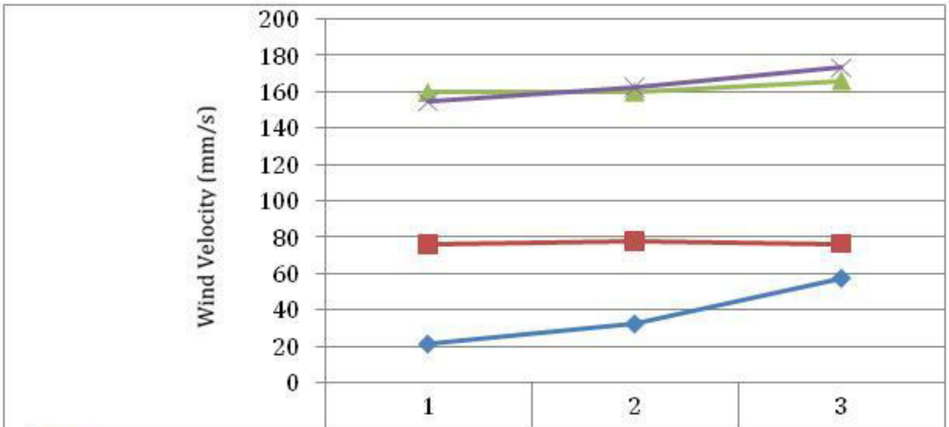


Fig. 3 Wind velocity measurement points inside 'test house'.

3. Result and Discussion

3.1. Traditional House with Wall Opening

Wind velocity inside Minahasa Traditional House with wall opening (TM1) is between 21 – 57 mm/s. From simulation's results (figure 4), TM1 recorded a higher internal airflow when stilts height is 3 meters (57.5 mm/s). Wind velocity inside TM1 is increased significantly when stilts are higher.



	1	2	3
TM1 - Wall Opening	21.2	32.2402	57.418
TM4 - Roof Opening	76.111	78.112	76.599
TM2 - Wall+Roof Opening	159.688	160.077	166.261
TM3 - Wall+Roff+Floor Opening	154.505	162.603	173.403

Fig. 4 Indoors air velocity (mm/s) and Stilts Height (m) in relation to opening positions

3.2. Traditional House with Roof

Minahasa traditional house with roof opening (TM4) has better wind velocity compared to the ones with wall opening (TM1). Wind velocity is between 76 – 80 mm/s for TM4, compared to 21 – 57 mm/s of TM1. However the simulation showed that there is no relation between stilts height and wind velocity for this type of houses. The wind velocity inside this type of house is relatively constant although the stilts were higher.

3.3. Traditional House with Wall and Roof

Combination between wall and roof opening improved the wind velocity inside the houses significantly. Simulation showed that the wind velocity is doubled when wall and roof opening are applied into the houses. Wind velocities inside the houses (TM2) are between 159 – 166 mm/s. The highest wind velocity (166.261 mm/s) occurred on TM2 with 3-meters stilts height. This condition is similar to the one of traditional house will wall opening (TM1) that the highest wind velocity is occurred in the house with the highest stilts height.

3.4. Traditional House with Wall, Roof and Floor Opening

3.4.1. Wind Velocity Beneath the Floor

Simulation's results (table 2 and figure 5) showed that the strongest wind velocity is occurred in the front area of 'kolong' and then decreased when reach the rear end. This condition happed in all stilt heights. This result indicated that the best location to put floor opening for natural ventilation is in the front area of 'kolong' or close to wind source.

Table 2. Wind speed beneath the floor.

No	Code	Wind Velocity (mm/s)			Stilts Height
		Point 2 (front)	Point 3 (middle)	Point 4 (rear)	
1	TM1	1050.72	983.298	915.797	1M
2	TM4	997.753	937.846	846.647	1M
3	TM2	977.957	934.584	843.363	1M
4	TM3	974.931	731.25	702.335	1M
5	TM1	907.433	914.831	894.434	2M
6	TM4	949.579	896.201	865.201	2M
7	TM2	970.338	936.468	884.409	2M
8	TM3	825.702	746.039	755.349	2M
9	TM1	1000.61	945.498	936.84	3M
10	TM4	945.125	870.342	857.681	3M
11	TM2	849.569	803.953	806.831	3M
12	TM3	977.09	845.232	831.158	3M

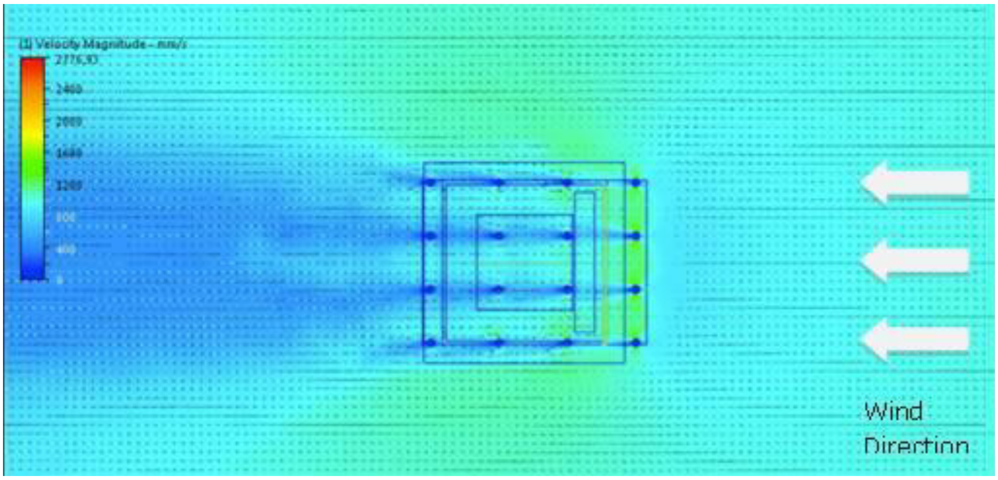


Fig. 5 Simulation of wind velocity beneath floor on test model 3-3 (TM3-3).

3.4.2. Traditional House with Wall, Roof and Floor

Highest wind velocity inside the houses is recorded in Minahasa Traditional House with Wall, Roof and Floor Opening (TM3). The velocity is between 154 -173 mm/s for stilts height of 1 – 3meters. There is 5% increase of wind velocity in TM3 with 3 meters stilts (TM3-3) compared to TM2 with the same height (TM2-3). This result show that floor opening in front area of the floor is improving wind velocity inside the house, therefore M.M. Tahir, et al. suggestion on improving thermal comfort on raised floor house by introducing alternative floor construction, adjustable floor louvers is confirmed.

Low increase in wind velocity showed that floor openings design that effectively 'catch' wind is needed to improve this condition. Wind velocity measurement on the floor opening (see figure 6) showed a wind velocity of 88.4 mm/s, which is less than 10% of wind velocity recorded on point 2 (977.09 mm/s).

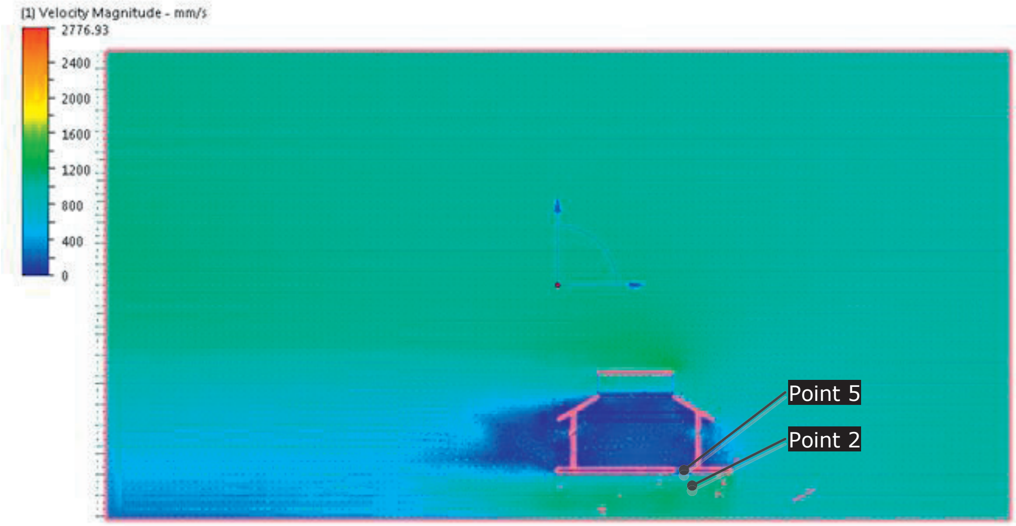


Fig. 6 Velocity magnitude of test model 3 – 3.

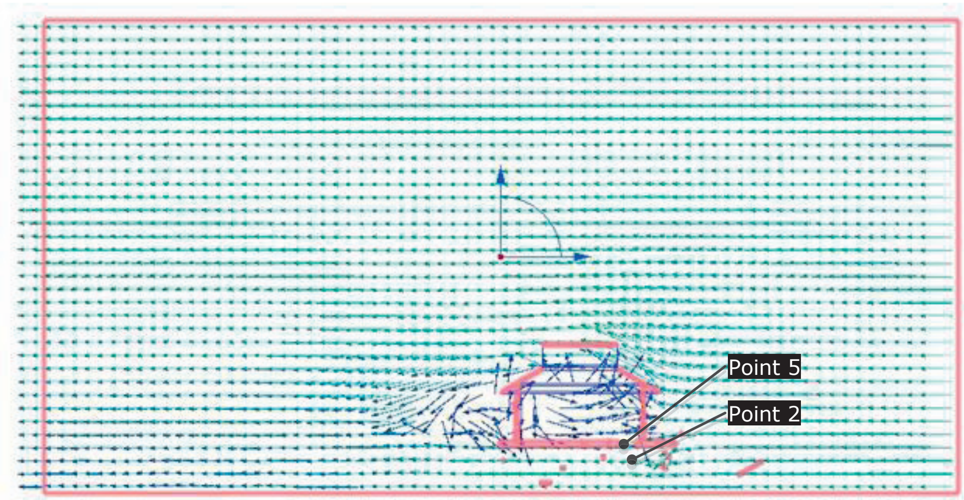


Fig. 7 Velocity vector of test model 3 - 3.

4. Conclusion

Computational Fluid Dynamic (CFD) Simulation can provide early information for building designer in an attempt to create thermal comfort. In the case of Minahasa Traditional Building, CFD simulation result provides information such as:

- Stilts height contributes to create better thermal comfort. Simulations results showed that higher stilts height is higher wind velocity inside the test house.

- Simulation results showed that houses with roof opening has higher internal wind velocity compared to houses with wall opening. This condition similar to previous condition where higher stilts contribute to higher velocity. Both showed that opening altitude from the ground is contributing to wind velocity perceived by resident. This is consistent with the nature of the wind speed that increases with height and is lower towards the ground due to frictional drag.
- Roof combined with wall opening is increase internal wind velocity almost double compared to ones with wall or roof opening.
- Floor opening is proven to improve wind velocity inside the raised floor houses. However full potential of airflow beneath the building need to be optimized by introducing effective floor opening design that can catch wind with higher velocity into the houses.
- Further research on 'bouyancy-driven ventilation' application on raised floor house such as solar chimney is suggested. Solar chimney application in combination with 'wind driven ventilation' on raised floor house is potentially improving wind velocity inside the house. Area beneath the house or 'kolong' that shaded during daytime will make air temperature in this area lower and suitable for air intake. Temperature difference between 'kolong' and roof is expected to generate high airflow.

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